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Report of the United Nations Scientific Committee on the Effects of Atomic Radiation

Sixtieth session
(27-31 May 2013)

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Note

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Chapter I

Introduction

1. Since the establishment of the United Nations Scientific Committee on the Effects of Atomic Radiation by the General Assembly in its resolution 913 (X) of 3 December 1955, the mandate of the Committee has been to undertake broad assessments of the sources of ionizing radiation and its effects on human health and the environment.[1] In pursuit of its mandate, the Committee thoroughly reviews and evaluates global and regional exposures to radiation. The Committee also evaluates evidence of radiation-induced health effects in exposed groups and advances in the understanding of the biological mechanisms by which radiation-induced effects on human health or on non-human biota can occur. Those assessments provide the scientific foundation used, inter alia, by the relevant agencies of the United Nations system in formulating international standards for the protection of the general public and workers against ionizing radiation;[2] those standards, in turn, are linked to important legal and regulatory instruments.

2. Exposure to ionizing radiation arises from naturally occurring sources (such as from outer space and radon gas emanating from rocks in the Earth) and from sources with an artificial origin (such as medical diagnostic and therapeutic procedures; radioactive material resulting from nuclear weapons testing; energy generation, including by means of nuclear power; unplanned events such as the nuclear power plant accidents at Chernobyl in 1986 and following the great east-Japan earthquake and tsunami of March 2011; and workplaces where exposure to artificial or naturally occurring sources of radiation may be increased).

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[1] The United Nations Scientific Committee on the Effects of Atomic Radiation was established by the General Assembly at its tenth session, in 1955. Its terms of reference are set out in resolution 913 (X). The Committee was originally composed of the following Member States: Argentina, Australia, Belgium, Brazil, Canada, Czechoslovakia (later succeeded by Slovakia), Egypt, France, India, Japan, Mexico, Sweden, Union of Soviet Socialist Republics (later succeeded by the Russian Federation), United Kingdom of Great Britain and Northern Ireland and United States of America. The membership of the Committee was subsequently enlarged by the Assembly in its resolution 3154 C (XXVIII) of 14 December 1973 to include the Federal Republic of Germany (later succeeded by Germany), Indonesia, Peru, Poland and the Sudan. By its resolution 41/62 B of 3 December 1986, the Assembly increased the membership of the Committee to a maximum of 21 members and invited China to become a member. In its resolution 66/70 of 9 December 2011, the Assembly further enlarged the membership of the Committee to 27 and invited Belarus, Finland, Pakistan, the Republic of Korea, Spain and Ukraine to become members.

[2] For example, the international basic safety standards for protection against ionizing radiation and for the safety of radiation sources, currently co-sponsored by the International Labour Organization, the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development and the Pan American Health Organization.

Chapter II

Deliberations of the United Nations Scientific Committee on the Effects of Atomic Radiation at its sixtieth session

3. The Scientific Committee held its sixtieth session in Vienna from 27 to 31 May 2013.[3] Carl-Magnus Larsson (Australia), Emil Bédi (Slovakia) and Yoshiharu Yonekura (Japan) served as Chair, Vice-Chair and Rapporteur, respectively. The Committee took note of General Assembly resolution 67/112 on the effects of atomic radiation.

A. Completed evaluations

4. The Committee discussed in detail two substantive scientific documents. The principal findings of those two documents are summarized in a scientific report (see chap. III below) and, together with the two detailed scientific annexes that underpin the findings, will be published separately in the usual manner, after comments from the Committee have been addressed.

5. The first document reported the results of an assessment of the levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami. The General Assembly, in its resolution 66/70, had endorsed the Committee's decision at its fifty-eighth session to conduct that assessment. The Committee acknowledged that it had been a major undertaking that had required efforts well beyond the resources normally available to the Committee and its secretariat. Over 80 experts from 18 countries and 5 international organizations had been involved in the work, constituting a major contribution in kind, and prepared material for the Committee's scrutiny at its sixtieth session. The experts had collected and reviewed data and information, and defined methodologies and processes for ensuring the quality of the data and for their use. Germany, Sweden and Switzerland had made financial contributions to the general trust fund to support the work of the Committee in this regard. An expert (offered by the Government of Japan under a non-reimbursable loan arrangement) had been assisting the secretariat in Vienna.

6. There were many sources of data: (a) specific datasets in electronic formats and supplementary information requested of the Government of Japan and other authenticated Japanese sources; (b) results of measurements and evaluations made by other United Nations Member States; (c) datasets made available by international organizations, including the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and the World Meteorological

[3] The sixtieth session of the Committee was also attended by observers for FAO, WHO, the International Agency for Research on Cancer, the World Meteorological Organization (WMO), IAEA, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the European Commission, the International Commission on Radiological Protection, and the International Commission on Radiation Units and Measurements.

Organization; (d) information and independent analyses published in peer-reviewed scientific journals; and (e) measurements made by non-governmental organizations.

7. The Committee also discussed a substantive scientific document that represented an extensive review of the effects of exposure to ionizing radiation during childhood. The Committee had decided at its fifty-seventh session (16-20 August 2010), in deliberations on its future programme of work, that it should undertake to address radiation risks for and effects on children, to help clarify how those risks and effects were different for children and adults. The delegation of the United States of America had led the preparation of detailed technical documents on this subject, which had been discussed at the fifty-eighth (23-27 May 2011) and fifty-ninth sessions (23-27 May 2012).

B. Present programme of work

1. Radiation exposures from electricity generation and an updated methodology for estimating human exposures due to radioactive discharges

8. The Committee discussed two progress reports, one on an evaluation of radiation exposures from electricity generation and the other on updating the Committee's methodology for estimating human exposures due to radioactive discharges into the environment. The Committee noted that the review and update of the existing methodology was well advanced. It noted that electronic spreadsheets were being developed that would implement the methodology for use in conducting the assessment of radiation exposures of populations from various types of electricity generation. The Committee anticipated that both documents would be ready for final scrutiny at its sixty-first session.

2. Biological effects from selected internal emitters

9. The Committee discussed progress on evaluations of the biological effects of exposure to selected internal emitters, addressing two specific radionuclides: tritium and uranium. It considered that further work was needed, but envisaged that the two components might be ready for detailed discussion at the Committee's sixty-first session.

3. Epidemiology of low-dose-rate exposures of the public to natural and artificial environmental sources of radiation

10. The Committee discussed progress on an evaluation of epidemiological studies of low-dose-rate exposures of the public to naturally occurring and artificial environmental sources of radiation. The Committee acknowledged that the work was progressing but envisaged that it might not be completed before the sixty-second session.

4. Development of an evaluation of medical exposures

11. The Committee took note of a progress report by the secretariat on developing an evaluation of medical exposures. Because (a) exposures of patients undergoing medical procedures represented the most significant source of artificial exposure to ionizing radiation, (b) technology and practices in this area were changing rapidly

and (c) this was a thematic priority of the Committee's strategic plan (2009-2013), the Committee had requested the secretariat to prepare a detailed plan for a report on this subject. It had also requested the secretariat to initiate the Committee's next Global Survey of Medical Radiation Usage and Exposures and to foster close cooperation with other relevant international organizations (such as IAEA and WHO), as appropriate. A web-based questionnaire on medical exposures had been developed and was being tested. The secretariat planned to initiate the survey during 2013 and to obtain feedback from the Committee at its sixty-first session on preliminary findings, with a view to completing the evaluation thereafter.

12. The Committee suggested that the General Assembly might (a) encourage Member States, the relevant organizations of the United Nations system and other pertinent organizations to provide further relevant data about doses, effects and risks from various sources of radiation, which would help greatly in the preparation of future reports of the Committee to the Assembly; and (b) encourage IAEA, WHO and other relevant organizations to further collaborate with the Committee's secretariat to establish and coordinate the arrangements for the periodic collection and exchange of data on radiation exposures of the general public, workers and, in particular, patients.

5. Outreach activities

13. The Committee took note of progress reports by the secretariat on outreach activities, in particular plans for the dissemination of the Committee's report on the levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami. It took note of the progress that the secretariat had made in enhancing the public website of the Committee, developing leaflets and posters and updating a booklet to explain in plain language the findings of its recent reports.

C. Strategic plan for 2014-2019

14. The Committee discussed a strategic plan to provide vision and direction for all its activities during the period 2014-2019, to facilitate results-based programming by the secretariat, to help foster the management of sufficient, assured and predictable resources and to improve planning and coordination among the various parties involved.

15. The Committee considered that its strategic objective for the period 2014-2019 was to increase awareness and deepen understanding among decision makers, the scientific community and civil society with regard to levels of exposure to ionizing radiation and the related health and environmental effects as a sound basis for informed decision-making on radiation-related issues.

16. The Committee identified its thematic priorities for the period: (a) the global impact of energy production (including follow-up of the radiological consequences of the 2011 accident at the Fukushima Daiichi nuclear power station) and of the rapidly expanding use of ionizing radiation in medical diagnosis and treatment; and (b) radiation effects at low doses and low dose rates.

17. Further strategic shifts were envisaged in order to better meet the needs of Member States, including: (a) further streamlining the Committee's scientific evaluation processes to complete both wide-ranging summary reports on the levels and effects of radiation exposure and preparing special reports that respond to emerging issues as the need arises; (b) further using intersessional expert groups to develop assessment methodologies, conduct evaluations and maintain surveillance on emerging issues; (c) developing networks of experts, scientific focal points in Member States and centres of excellence to facilitate access to expertise; (d) further enhancing mechanisms for data collection, analysis and dissemination; and (e) further raising awareness and improving dissemination of the Committee's findings in readily understandable formats for decision makers and the public.

D. Future programme of work

18. At its previous session, the Committee had decided that the work to assess the levels of exposure and radiation risks resulting from the nuclear accident following the great east-Japan earthquake and tsunami of March 2011 and to complete an extensive review of the effects of radiation exposure on children should take priority over other evaluations and activities that had been initiated as part of the present programme of work. Because those two studies were to be completed and published during the following months, the Committee, in discussions about its future programme of work, agreed to focus on completing other outstanding evaluations that had been delayed owing to the unexpected work resulting from the accident at the Fukushima Daiichi nuclear power station, and not to introduce further new topics at this stage.

E. Administrative issues

19. The Committee welcomed developments in streamlining procedures for publishing the Committee's reports as sales publications. Nevertheless the Committee suggested that the General Assembly might request the United Nations Secretariat to continue to streamline the procedures, recognizing that, while maintaining quality, the timeliness of their publication is paramount to fulfil the expected accomplishments approved in the programme budget, and expecting that the report ought to be published within the same year in which it is approved.

20. The Committee recognized that, because of the need to maintain the intensity of its work and particularly to improve dissemination of its findings, voluntary contributions to the general trust fund established by the Executive Director of the United Nations Environment Programme to receive and manage voluntary contributions to support the work of the Committee would be beneficial. The Committee suggested that the General Assembly might encourage Member States to consider making voluntary contributions to the general trust fund for this purpose or to make contributions in kind.

21. The Committee agreed to hold its sixty-first session in Vienna from 26 to 30 May 2014.

Chapter III

Scientific findings

22. Two scientific annexes (published separately) provide the rationale for the conclusions expressed in the present chapter.

A. Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami

1. The accident and the release of radioactive material into the environment

23. On 11 March 2011, at 14.46 local time, a 9.0-magnitude earthquake occurred near Honshu, Japan, creating a devastating tsunami that left a trail of death and destruction in its wake. The earthquake and subsequent tsunami, which flooded over 500 square kilometres of land, resulted in the loss of more than 20,000 lives and destroyed property, infrastructure and natural resources. They also led to the worst civil nuclear disaster since the one at Chernobyl in 1986. The loss of off-site and on-site electrical power and compromised safety systems at the Fukushima Daiichi nuclear power station led to severe core damage to three of the six nuclear reactors on the site; this resulted in the release, over a prolonged period, of very large amounts of radioactive material into the environment.

24. As an immediate response, the Government of Japan recommended the evacuation of about 78,000 people living within a 20-km radius of the power plant and the sheltering in their own homes of about 62,000 other people living between 20 and 30 km from the plant. Later, in April 2011, the Government recommended the evacuation of about 10,000 more people living farther to the north-west of the plant (referred to as the deliberate evacuation area), because of the high levels of radioactive material on the ground. The evacuations greatly reduced (by up to a factor of 10) the levels of exposure that would otherwise have been received by those living in those areas. However, the evacuations themselves also had repercussions for the people involved, including a number of evacuation-related deaths and the subsequent impact on mental and social well-being (for example, because evacuees were separated from their homes and familiar surroundings, and many lost their livelihoods).

25. The information reviewed by the Committee implies atmospheric releases of iodine-131 and caesium-137 (two of the more significant radionuclides from the perspective of exposures to people and the environment) in the ranges of 100 to 500 petabecquerels (PBq) and 6 to 20 PBq, respectively; for its further work, the Committee used estimates that lie within those ranges. These estimates are lower, indicatively, by a factor of about 10 and 5, respectively, than corresponding estimates of atmospheric releases resulting from the Chernobyl accident. Winds transported a large portion of the atmospheric releases to the Pacific Ocean. In addition, liquid releases were discharged directly into the surrounding sea. The direct discharges amounted to perhaps 10 and 50 per cent of the corresponding atmospheric discharges for iodine-131 and caesium-137, respectively; low-level releases into the ocean were still ongoing in May 2013.

2. Dose assessment

26. Iodine-131 (with a short half-life of 8 days) and caesium-137 (with a much longer half-life of 30 years) were found to be the two most important radionuclides for dose assessment. For those two radionuclides, the affected tissues and the time span of the exposure were quite different. Iodine-131 tended to accumulate in the thyroid gland for a few weeks after the release and delivered a dose primarily to that organ. Caesium-137 was deposited on the ground; it delivers a dose to the whole body over many years following the release.

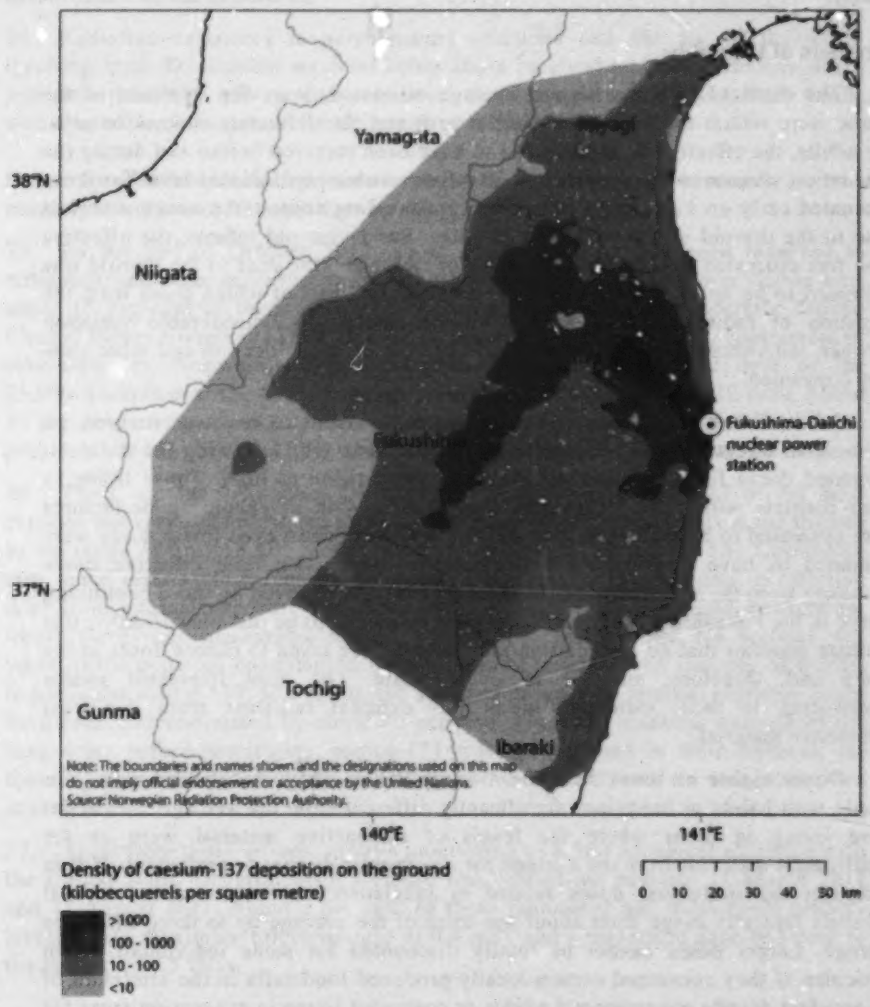
27. The Committee has made estimates of the radiation exposures of various categories of people, namely: members of the public exposed as a result of the release of radioactive material into the environment; occupationally exposed workers employed at the Fukushima Daiichi nuclear power station at the time of the accident and those subsequently involved in on-site recovery operations; and emergency personnel involved in on-site and/or off-site activities. Where practicable, the Committee based its evaluations on results of individual monitoring. Occupationally exposed workers and emergency personnel were generally monitored for exposure to sources of radiation external to the body (external exposures) and for exposures from intakes of radioactive materials into the body (internal exposures) where these may have been significant.

28. At the time the Committee's evaluation began, few direct measurements of internal exposures were available for members of the public. These were insufficient for the Committee to estimate doses for the areas in Japan most affected by the accident. Therefore, the Committee had to rely on the use of various models to estimate doses on the basis of measured, or predicted, levels of radioactive material in the environment and their transfer through the environment to humans (for example, the figure illustrates the pattern — derived from measurements — of caesium-137 deposition in the areas of Japan most affected as a result of the accident). Of necessity, modelling had to be used to forecast potential doses in the future.

Figure

Deposition of caesium-137 on the ground in the Fukushima Prefecture and neighbouring prefectures based on measurement data adjusted to 14 June 2011

This map is derived by interpolating between measurements; its aim is to portray the overall pattern of deposition levels and extent rather than to indicate precise demarcation areas.



29. The estimated effective doses resulting from the accident at the Fukushima Daiichi nuclear power station can be put in perspective by comparing them with those received from exposures to radiation sources of natural origin (such as cosmic rays and naturally occurring radioactive material in food, air, water and other parts of the environment). The Japanese people receive an effective dose of radiation

from naturally occurring sources of, on average, about 2.1 millisieverts (mSv) annually and a total of about 170 mSv over their lifetimes. The Committee's latest estimate for the global average annual exposure to naturally occurring sources of radiation is 2.4 mSv and ranges between about 1 and 13 mSv, while sizeable population groups receive 10 to 20 mSv annually.[4] Absorbed doses to individual organs are expressed in milligrays (mGy). The average annual absorbed dose to the thyroid from naturally occurring sources of radiation is typically of the order of 1 mGy.

(a) Members of the public

30. The districts with the highest average estimated doses for members of the public were within the 20-km evacuation zone and the deliberate evacuation area. For adults, the effective dose estimated to have been received before and during the evacuation was, on average, less than 10 mSv and about half of that level for those evacuated early on 12 March 2011. The corresponding estimated average absorbed dose to the thyroid was up to about 30 mGy. For 1-year-old infants, the effective dose was estimated to be about twice that for adults and the dose to the thyroid was estimated to be up to about 70 mGy, as much as one half of which arose from the ingestion of radioactivity in food. However, there was considerable variation between individuals around this value, depending on their location and what food they consumed.

31. Adults living in the city of Fukushima were estimated to have received, on average, an effective dose of about 4 mSv in the first year following the accident; estimated doses for 1-year-old infants were about twice as high. Those living in other districts within the Fukushima Prefecture and in neighbouring prefectures were estimated to have received comparable or lower doses; even lower doses were estimated to have been received elsewhere in Japan. Lifetime effective doses (resulting from the accident) that, on average, could be received by those continuing to live in the Fukushima Prefecture have been estimated to be just over 10 mSv; this estimate assumes that no remediation measures will be taken to reduce doses in the future and, therefore, may be an overestimate. The most important source contributing to these estimated doses was external radiation from deposited radioactive material.

32. Doses higher or lower than the average values above can be estimated for people with habits or behaviour significantly different from the average, and/or for those living in areas where the levels of radioactive material were or are significantly different from the average for a particular district or prefecture. Within a district the individual doses related to inhalation and exposure to external radiation typically range from about one third of the average up to three times the average. Larger doses cannot be totally discounted for some individuals — in particular, if they consumed certain locally produced foodstuffs in the aftermath of the accident despite governmental advice or continued living in evacuation areas for an extended period. Some infants may have received thyroid doses of 100 mGy or more.

[4] *Official Records of the General Assembly, Sixty-third Session, Supplement No. 46* (A/63/46), table 1.

33. Some information on internal doses, based on direct measurements of radioactivity in people, was available shortly after the accident, but more information became available after the Committee completed its dose estimations. Collectively, these measurements of radioactive content of the thyroid and of the whole body indicated doses due to internal exposure lower than those estimated by the Committee, by a factor of about 3 to 5 for thyroid doses and up to about 10 for whole-body doses. Thus, the Committee considers that its dose estimates may overestimate actual exposures.

34. Radiation exposures in neighbouring countries and the rest of the world resulting from the accident were far below those received in Japan; effective doses were less than 0.01 mSv, and thyroid doses were less than 0.01 mGy; these levels would be of no consequence for the health of individuals.

(b) Fukushima Daiichi nuclear power station workers, emergency personnel, municipal workers and volunteers

35. By the end of October 2012, about 25,000 workers had been involved in mitigation and other activities at the Fukushima Daiichi nuclear power station site; about 15 per cent of them were employed directly by the plant operator (Tokyo Electric Power Company (TEPCO)), while the rest were employed by contractors or subcontractors. According to their records, the average effective dose of the 25,000 workers over the first 19 months after the accident was about 12 mSv. About 35 per cent of the workforce received total doses of more than 10 mSv over that period, while 0.7 per cent of the workforce received doses of more than 100 mSv.

36. The Committee examined the data on internal exposure for 12 of the most exposed workers and confirmed that they had received absorbed doses to the thyroid in the range of 2 to 12 Gy, mostly from inhalation of iodine-131. The Committee also found reasonable agreement between its independent assessments of effective dose from internal exposure and those reported by TEPCO for those workers for whom there were measurable levels of iodine-131 in the body. No account was taken of the potential contribution from intakes of shorter-lived isotopes of iodine, in particular iodine-133; as a result, the assessed doses from internal exposure could have been underestimated by about 20 per cent. For many workers, because of the long delay before monitoring, iodine-131 was not detected in their thyroids; for those workers the internal doses estimated by TEPCO and its contractors are uncertain.

37. Apart from those groups, in vivo monitoring of 8,380 personnel affiliated with the United States Department of Defense was carried out between 11 March 2011 and 31 August 2011. About 3 per cent of those monitored had measurable activity levels with a maximum effective dose of 0.4 mSv and a maximum absorbed dose to the thyroid of 6.5 mGy.

3. Health implications

38. No radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident.

39. The doses to the general public, both those incurred during the first year and estimated for their lifetimes, are generally low or very low. No discernible increased incidence of radiation-related health effects are expected among exposed members

of the public or their descendants. The most important health effect is on mental and social well-being, related to the enormous impact of the earthquake, tsunami and nuclear accident, and the fear and stigma related to the perceived risk of exposure to ionizing radiation. Effects such as depression and post-traumatic stress symptoms have already been reported. Estimation of the occurrence and severity of such health effects are outside the Committee's remit.

40. For adults in Fukushima Prefecture, the Committee estimates average lifetime effective doses to be of the order of 10 mSv or less, and first-year doses to be one third to one half of that. While risk models by inference suggest increased cancer risk, cancers induced by radiation are indistinguishable at present from other cancers. Thus, a discernible increase in cancer incidence in this population that could be attributed to radiation exposure from the accident is not expected. An increased risk of thyroid cancer in particular can be inferred for infants and children. The number of infants that may have received thyroid doses of 100 mGy is not known with confidence; cases exceeding the norm are estimated by model calculations only, and in practice they are difficult to verify by measurement.

41. For the 12 workers whose exposure data were scrutinized by the Committee and who were estimated to have received absorbed doses to the thyroid from iodine-131 intake alone in the range of 2 to 12 Gy, an increased risk of developing thyroid cancer and other thyroid disorders can be inferred. More than 160 additional workers received effective doses currently estimated to be over 100 mSv, predominantly from external exposures. Among this group, an increased risk of cancer would be expected in the future. However, any increased incidence of cancer in this group is expected to be indiscernible because of the difficulty of confirming such a small incidence against the normal statistical fluctuations in cancer incidence. Workers exposed to doses above 100 mSv will be specially examined, including through annual examinations of the thyroid, stomach, large intestine and lungs for potential late radiation-related health effects.

42. In June 2011, a health survey of the local population (the Fukushima Health Management Survey) was initiated. The survey, which began in October 2011 and is planned to continue for 30 years, covers all 2.05 million people living in Fukushima Prefecture at the time of the earthquake and reactor accident. It includes a thyroid ultrasound survey of 360,000 children aged up to 18 years at the time of the accident, using modern high-efficiency ultrasonography, which increases the ability to detect small abnormalities. Increased rates of detection of nodules, cysts and cancers have been observed during the first round of screening; however, these are to be expected in view of the high detection efficiency. Data from similar screening protocols in areas not affected by the accident imply that the apparent increased rates of detection among children in Fukushima Prefecture are unrelated to radiation exposure.

4. Radiation exposures and effects on non-human biota

43. Exposures of selected non-human biota in the natural environment were also estimated. The doses and associated effects of radiation on non-human biota following the accident were evaluated against the Committee's previous evaluations of such effects.[5] Exposures of both marine and terrestrial non-human biota following the accident were, in general, too low for acute effects to be observed, though there may have been some exceptions because of local variability:

(a) Effects on non-human biota in the marine environment would be confined to areas close to where highly radioactive water was released into the ocean;

(b) Continued changes in biomarkers for certain terrestrial organisms, in particular mammals, cannot be ruled out, but their significance for population integrity of those organisms is unclear. Any radiation effects would be restricted to a limited area where the deposition of radioactive material was greatest; beyond that area, the potential for effects on biota is insignificant.

44. While it was not within the scope of the Committee's evaluation, it is important to note that the effects of the protective actions and any remediation conducted to reduce human exposure have a significant impact on, inter alia, environmental goods and services, resources used in agriculture, forestry, fisheries and tourism, and amenities used in spiritual, cultural and recreational activities.

B. Effects of radiation exposure of children

45. Epidemiological studies reported in the literature vary with regard to the specific age groups they consider. For the purposes of the Committee's evaluation of the effects of radiation exposure on children, the term "children", in contrast to "adults", included those exposed as infants, children and adolescents. The evaluation did not specifically address effects of in utero exposure to radiation because such information is contained in other comprehensive reports. The evaluation also did not address the many beneficial uses of radiation exposure for children, such as in medical diagnosis and therapy, which are outside the mandate of the Committee.

46. Sources of exposure to children that are of particular interest include accidental exposures, and specific regions with enhanced levels of natural background radiation, as well as diagnostic and therapeutic procedures. The data reviewed by the Committee were derived from studies covering a wide range of doses, variable dose rates, whole and partial body exposure and children of different ages. The effects described in the annex are often very specific to a given exposure scenario.

47. At its sixtieth session the Committee considered the effects of radiation exposure of children and reached the following conclusions:

(a) For a given radiation dose, children are generally at more risk of tumour induction than are adults. Cancers potentially induced by exposure to ionizing

[5] See *Official Records of the General Assembly, Fifty-first Session, Supplement No. 46* (A/51/46), and *Sixty-third Session, Supplement No. 46* (A/63/46).

radiation at young ages may occur within a few years, but also decades later. In its report on its fifty-fourth session, the Committee stated that estimates of lifetime cancer risk for those exposed as children were uncertain and might be a factor of 2 to 3 times as high as estimates for a population exposed at all ages.[6] That conclusion was based on a lifetime risk projection model combining the risks of all tumour types together;

(b) The Committee has reviewed evolving scientific material and notes that radiogenic tumour incidence in children is more variable than in adults and depends on the tumour type, age and gender. The term "radiation sensitivity" with regard to cancer induction refers to the rate of radiogenic tumour induction. The Committee reviewed 23 different cancer types. Broadly, for about 25 per cent of these cancer types, including leukaemia and thyroid, skin, breast and brain cancer, children were clearly more radiosensitive. For some of these types, depending on the circumstances, the risks can be considerably higher for children than for adults. Some of these cancer types are highly relevant for evaluating the radiological consequences of accidents and of some medical procedures;

(c) For about 15 per cent of the cancer types (e.g. colon cancer), children appear to have about the same radiosensitivity as adults. For about 10 per cent of cancer types (e.g. lung cancer), children appear less sensitive to external radiation exposure than adults. For about 20 per cent of cancer types (e.g. oesophagus cancer), the data are too weak to draw a conclusion regarding any differences in risk. Finally, for about 30 per cent of cancer types (e.g. Hodgkin's disease and prostate, rectum and uterus cancer), there is only a weak relationship or none at all between radiation exposure and risk at any age of exposure;

(d) At present, projections of lifetime risk for specific cancer types following exposure at young ages are statistically insufficient. Estimates currently do not adequately capture the known variations, and additional studies are needed;

(e) For direct effects that occur after high (either acute or fractionated) doses (so-called deterministic health effects), the differences in outcome between exposure in childhood and in adulthood are complex and can be explained by the interaction of different tissues and mechanisms. These effects may be seen after radiation therapy or following high exposures in accidents. The difference between the radiation sensitivity of children and that of adults for deterministic effects in a specific organ is often not the same as the difference for cancer induction. There are some instances in which childhood exposure poses more risk than adulthood exposure (e.g. risk of cognitive defects, cataracts and thyroid nodules). There are other instances where the risk appears to be about the same (e.g. risk of neuroendocrine abnormalities), and there are a few instances where children's tissues are more resistant (e.g. lungs and ovaries);

(f) Because of all the above considerations, the Committee recommends that generalizations on the risks of effects of radiation exposure during childhood should be avoided. Attention should be directed to specifics of the exposure, age at exposure, absorbed dose to certain tissues and the particular effects of interest;

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[6] *Official Records of the General Assembly, Sixty-first Session, Supplement No. 46* and corrigendum (A/61/46 and Corr.1) paras. 21-22.

(g) There have been many studies of possible heritable effects following radiation exposure; such studies were reviewed by the Committee in 2001. It has been generally concluded that no heritable effects in humans due to radiation exposure have been explicitly identified (specifically in studies of offspring of survivors of the atomic bombings). Over the past decade, there have been additional studies that have focused on survivors of childhood and adolescent cancer following radiotherapy, where gonadal doses are often very high. There is essentially no evidence of an increase in chromosomal instability, minisatellite mutations, transgenerational genomic instability, change in sex ratio of offspring, congenital anomalies or increased cancer risk in the offspring of parents exposed to radiation. One reason for this is the large fluctuation in the spontaneous incidence of these effects;

(h) Health effects and risks are dependent on a number of physical factors. Because children have smaller body diameters and there is less shielding by overlying tissues, the dose to their internal organs will be larger than for an adult for a given external exposure. Because they are also shorter than adults, children may receive a higher dose from radioactivity distributed in and deposited on the ground. These factors are important when considering doses to populations in some areas with high levels of radionuclides in and on the ground. In diagnostic medical exposure, children may receive significantly higher doses than adults for the same examination if the technical parameters for delivering the dose are not specifically adapted;

(i) Regarding internal exposure, because of the smaller size of infants and children, and thus because their organs are closer together, radionuclides concentrated in one organ irradiate other organs of children's bodies more than occurs in adults. There are also many other age-related factors involving metabolism and physiology that make a substantial difference in dose at different ages. Several radionuclides are of particular concern regarding internal exposure of children. Accidents involving releases of radioactive iodines (for example, in a nuclear power plant accident) can be significant sources of exposure of the thyroid gland, and thus have the potential to induce thyroid cancer. For a given intake, the dose to the thyroid for infants is eight or nine as large as that for adults. For intakes of caesium-137, there is very little difference in dose between children and adults. Internal exposure of children also occurs in the medical use of radionuclides. The spectrum of procedures normally performed on children is different from that performed on adults. Potentially higher doses in children are offset in practice by the use of a lower amount of administered radioactive material.

48. The Committee recognizes that continued research is needed to identify the full scope and expression of the differences in effects, mechanisms and risk from exposure to ionizing radiation for children and for adults. This is necessary because for a number of studies (such as of the atomic bombing survivors, children exposed to radioiodine after the Chernobyl accident and those who have had computed tomography scans), the lifetime results remain incomplete. Future long-term studies following childhood exposure will face significant difficulties owing to unlinked health records, administrative and political barriers and ethical and privacy considerations.

49. Important areas of future research and work also include evaluation of potential radiation effects for children: (a) in areas of high natural background

exposure; (b) after high-dose medical procedures involving interventional fluoroscopy; and (c) after cancer radiotherapy (including evaluation of potential interactions with other therapies). The Committee has identified the following areas for future research as well: development of databases on radiation doses for children who can be tracked in the long term; and evaluation of effects following whole and partial irradiation of juvenile organs. Studies at the molecular, cellular, tissue and juvenile animal level are potentially informative.

Appendix I

Members of national delegations attending the fifty-eighth to sixtieth sessions of the United Nations Scientific Committee on the Effects of Atomic Radiation

Argentina	A. J. González (Representative), A. Canoba, M. di Giorgio
Australia	C. M. Larsson (Representative), C. Baggoley, G. Hirth, S. B. Solomon, R. Tinker
Belarus	J. Kenigsberg (Representative), A. Stazharau, V. Ternov
Belgium	H. Vanmarcke (Representative), S. Baatout, H. Bijwaard, H. Bosmans, G. Eggermont, H. Engels, F. Jamar, L. Mullenders, H. Slaper, P. Smeesters, A. Wambersie, P. Willems
Brazil	J. Hunt (Representative), D. R. Melo (Representative), M. Nogueira Martins (Representative), M. C. Lourenço, L. Holanda Sadler Veiga
Canada	C. Purvis (Representative), B. Pieterson (Representative), N. E. Gentner (Representative), D. Boreham, K. Bundy, D. B. Chambers, J. Chen, S. Hamlat, R. Lane, C. Lavoie, E. Waller
China	Pan Z. (Representative), Chen Y., Du Y., Gao H., Liu J., Liu S., Pan S., Su X., Sun Q., Wang Y., Yang H., Zhang W., Zhu M.
Egypt	T. S. El-Din Ahmed (Representative), M.A.M. Gomaa (Representative)
Finland	S. Salomaa (Representative), A. Auvinen, E. Salminen
France	L. Lebaron-Jacobs (Representative), A. Rannou (Representative), E. Ansoborlo, M. Bourguignon, J.-R. Jourdain, F. Ménétrier, M. Tirmarche
Germany	W. Weiss (Representative), A. A. Friedl, K. Gehrcke, P. Jacob, T. Jung, G. Kirchner, J. Kopp, R. Michel, W. U. Müller
India	K. B. Sainis (Representative), B. Das, P. C. Kesavan, Y. S. Mayya, K. S. Pradeepkumar
Indonesia	S. Widodo (Representative), Z. Alatas, G. B. Prajogi, G. Witono, B. Zulkarnaen
Japan	Y. Yonekura (Representative), S. Akiba, T. Aono, N. Ban, M. Chino, K. Kodama, M. Kowatari, M. Nakano, O. Niwa, K. Ozasa, S. Saigusa, G. Suzuki, T. Takahashi, Y. Yamada, H. Yamagishi

Mexico	J. Aguirre Gómez (Representative)
Pakistan	M. Ali (Representative), Z. A. Baig
Peru	A. Lachos Dávila (Representative), B. M. García Gutiérrez
Poland	M. Waligórski (Representative), L. Dobrzyński, M. Janiak, M. Kruszewski
Republic of Korea	K.-W. Cho (Representative), S. H. Na (Representative), K.-H. Do, D.-K. Keum, J.-I. Kim, J. K. Lee, S. Y. Nam
Russian Federation	M. Kiselev (Representative), A. Akleyev, R. Alexakhin, T. Azizova, V. Ivanov, N. Koshurnikova, A. Koterov, I. Kryshev, B. Lobach, O. Pavlovskiy, A. Rachkov, S. Romanov, A. Sazhin, S. Shinkarev
Slovakia	E. Bédi (Representative), M. Chorváth, Ž. Kantová, K. Petrová, L. Tomášek, I. Zachariášová
Spain	M. J. Muñoz González (Representative), M. T. Macías Domínguez, B. Robles Atienza, E. Vañó Carruana
Sudan	M.A.H. Eltayeb (Representative), I. Salih Mohamed Musa (Representative), E.A.E. Ali (Representative)
Sweden	L. Hubbard (Representative), L. Moberg (Representative), A. Almén, L. Gedda, J. Johansson Barck-Holst
Ukraine	D. Bazyka (Representative)
United Kingdom of Great Britain and Northern Ireland	J. Harrison (Representative), J. Cooper (Representative), S. Bouffler, J. Simmonds, R. Wakeford
United States of America	F. A. Mettler Jr. (Representative), L. R. Anspaugh, J. D. Boice Jr., N. H. Harley, E. V. Holahan Jr., R. J. Preston

Appendix II

Scientific staff and consultants cooperating with the United Nations Scientific Committee on the Effects of Atomic Radiation in the preparation of its scientific report for 2013

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V. Golikov

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